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SECURITY INFORMATION

CENTRAL INTELLIGENCE AGENCY

INFORMATION FROM

FOREIGN DOCUMENTS OR RADIO BROADCASTS CD NO.

REPORT

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COUNTRY USSR

SUBJECT Scientific - Metals, metal substitutes,
plastic materials, lead substitutesDATE OF
INFORMATION 1953HOW
PUBLISHED Monthly periodical

DATE DIST. 24 Nov 1953

WHERE
PUBLISHED Moscow

NO. OF PAGES 6

DATE
PUBLISHED Apr 1953

LANGUAGE Russian

SUPPLEMENT TO
REPORT NO.

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SOURCE Za Ekonomiyu Materialov, No 4, pp 30-37SUBSTITUTES FOR NONFERROUS METALS IN USSR

The following excerpts from an article, "Developing the Pro-
duction of Substitutes for Nonferrous Metals," by Docent I. Klinov,
Candidate of Technical Sciences, in the monthly periodical Za
Ekonomiyu Materialov (For the Conservation of Materials), No 4,
April 1953.

During the postwar years, the Soviet Union has achieved considerable prog-
ress in manufacturing nonmetallic chemically stable materials on an organic base.
These materials serve in many cases as feasible substitutes for nonferrous metals
and in other cases as protection against corrosion for ferrous metals.

An especially urgent problem is the replacement of lead, which, being
practically the only acid-resisting metal, is widely applied in the machine-
building, metallurgical, paper-making, petroleum, and other branches of the na-
tional economy. In particular, lead consumption is high in the chemical industry
and related productions.

The appearance in the last 2-3 years of new materials, such as polyiso-
butylene, asbovinyl, and graphite, and the wider application of a comparatively
old material, viniplast, all used as lead substitutes, have promoted considerable
conservation of lead.

One of the most valuable lead substitutes is polyisobutylene, which is a
rubber like material. Products made on the base of polyisobutylenes are used as
anticorrosive protection and for facing metal, concrete, and wooden equipment.

Polyisobutylene is also used as interlaying material in lining apparatus
with silicate tiles to create an impervious layer. Application of polyisobutylene
also has the purpose of eliminating deformations which usually occur in linings
as a result of the difference in the expansion coefficients of metal and silicate
tiles.

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The basic principles of obtaining polyisobutylenes were developed in the Soviet Union by S. V. Lebedev and his students in the 1930s. Using the ideas and experience of Russian scientists, other countries have organized industrial production of polyisobutylenes, known under the trade names of "oppanol" in Germany and "vistanex" in the US.

Polyisobutylenes differ from each other by their molecular weight. Their gumlike properties appear only at molecular weights of 50,000 and higher. Polyisobutylenes with low molecular weight are viscous oillike liquids.

Principally, high-molecular polyisobutylenes of the P-100 and P-200 types, i.e., with molecular weights of 100,000 and 200,000, are produced in the USSR on an industrial scale. The polymerization of isobutylene for obtaining a high-molecular product is carried out at a temperature of about minus 100° C in the presence of a catalyst. Commercial polyisobutylene in sheet form, usually containing various admixtures, such as graphite, lampblack, asbestos, and talc, is made on machines used in the rubber industry. Polyisobutylene for lining is produced under the name PSG₂₀₀ as 0.8- x 5-m sheets of 2- to 3-mm thickness.

The major advantages of polyisobutylenes, as compared with rubbers, are the lack of a need for vulcanization and high resistance to aging with retention of elasticity in the temperature range from minus 55 to 60°. The physicomaterial properties of polyisobutylene of PSG₂₀₀ grade are as follows: tensile strength, 45-65 kg/sq cm; relative elongation, 475-550%; specific gravity, 1.32; Shore hardness, 67; plasticity, 0.09; and recovery value, 0.17 mm.

Polyisobutylene is soluble in aromatic solvents, mineral oils, paraffin, chloroform, and some other organic solvents. It is stable in mineral acids, alkalis, and other active media. Nitric acid has no effect on it at room temperature. In particular, polyisobutylene is stable in hydrochloric acid of high concentration, in sulfuric acid up to 70%, in acetic acid of various concentrations, in solutions of salts, in gaseous media, and in a number of organic compounds.

It is essential to notice that polyisobutylene, like viniplast, is weldable at 150-200° C. The strength of a welded joint amounts to 70-80% base-material strength. In contrast to viniplast, polyisobutylene may be welded without a welding rod.

Homogeneous joints of polyisobutylene sheets are also obtainable in the cold state by subjecting an overlapping joint to the proper pressure. However, this method is ineffective because of low productivity and difficulties of forming vertical irregular joints.

So-called "cold flow," i.e., deformation of material under load, is a deficiency of polyisobutylene. In cases where mechanical loading takes place, the protection of polyisobutylene with silicate tiles is recommended. Thus, the application of polyisobutylene as an independent supporting structural member is excluded. A similar protective facing is required when polyisobutylene is exposed to a temperature above 60°. Polyisobutylene is attached to metal, wood, or concrete by means of various glues. The adhesive strength amounts to 25 kg/sq cm for metal, 16 kg/sq cm for concrete, and 15 kg/sq cm for wood.

Polyisobutylene is now in use as lining material for containers, apparatus, pipes, and various equipment at a number of establishments, and is showing good results. A column 12 m high and 3 m in diameter, installed at a steam-electric power plant, is one of the largest structures for which polyisobutylene has been used as a substitute for lead.

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Asbovinyl is another essential substitute for a number of nonferrous metals. It is a plastic mass obtained by mixing pulverized acid-resistant asbestos with a binding substance, known in industry under the name of lac-ethanol. The binder, being a production waste material, is a solution of high-polymer acetylene derivatives of 40-50% concentration. As long ago as 1938, Engineer I. P. Shabodolov suggested asbovinyl as a substitute for nonferrous metals, but wide application of this material has occurred only during the last 2-3 years.

Asbovinyl is usually applied to the surface to be protected by the ordinary paring method and shows; upon setting, considerable adhesion with a coated surface. In its physicommechanical properties, the asbovinyl product is close to a generally known plastic material -- faolite -- but has a number of advantages over faolite or viniplast. The asbovinyl mass may be used as a lining for metal, concrete, ceramic and other materials, while the faolite mass has a low adhesive property.

The asbovinyl product may also be used in the fabrication of pipes, cocks, rectifying tower plates, and other similar articles. Asbovinyl possesses acid-resistant as well as alkali-resistant properties, depending on the type of asbestos used, and is a suitable material for low temperatures in the range between minus 40 and minus 50°. The asbovinyl product may be cured at room temperature or higher. Its manufacture requires no expensive or scarce raw materials and, in addition, preparation and application of lining material requires no special equipment.

The following are the physicommechanical properties of asbovinyl: specific gravity, 1.5-1.6; water absorption, 0.5-1.0%; tensile strength, 150-200 kg/sq cm; compressive strength, 150-300 kg/sq cm; bending strength, 250-300 kg per sq cm; hardness, 18-25 kg per sq mm; heat conductivity, 0.11 cal/m/hr °C; resistance to frost, up to minus 50° C; adhesiveness, 20-25 kg/sq cm; coefficient of linear expansion is low.

The composition of asbovinyl depends on its purpose. The ratio between binder and asbestos is of the order 1:1.3-1.5.

The asbovinyl paste is applied on a surface to be covered in the form of a three-layer coating 10-12 mm thick. Each coat should not exceed 3-4 mm in thickness. Curing is done by heating in a special chamber to 120°. Coatings on large pieces, which cannot be placed into a drying chamber, are cured in the open at a temperature of 15-20° for 30 days. To decrease the period of drying, a lining may be heated with hot air obtained by any method. When equipment with jackets or coils is lined, heating may be performed through the jackets with the aid of hot water and steam.

Since 1950, asbovinyl materials have been widely used not only for lining various equipment in the cellulose-paper industry, but also as substitutes for nonferrous metals -- chiefly lead -- in chemical, petroleum, and other branches of industry.

The fields of application of asbovinyl are defined by its durability in nonoxidizing mineral acids, in solutions of salts, in certain organic acids and solvents, in gases, and in weak solutions of alkalis, including, for example, hydrochloric acid up to 30% concentration, sulfuric acid up to 75%, bleaching powder, chlorobenzene, solution of caustic soda up to 30%, glacial acetic acid, etc. It should be remembered that asbovinyl deteriorates in nitric acid, hydrogen peroxide, and other oxidizing media. Asbovinyl may be used at temperatures up to 110-120°.

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A comparatively long experience in operating equipment lined with asbovinyl, particularly in the sulfite-cellulose and paper industry, has shown that in numerous cases this material is a very effective and sound substitute for lead and other critical materials.

Among the substitutes for nonferrous metals, impregnated graphite deserves to be mentioned. Its application as an independent structural material or in the form of lining tiles for metal, has not yet been developed properly in the Soviet Union because of the novelty of this material and insufficient familiarity of designers and technologists with its properties.

Impregnated graphite is one of the most promising materials in anticorrosive practice. Together with extremely high inertness toward the majority of active substances and the possibility of its use at high temperatures, depending on the nature of the impregnating agent, graphite has a number of other essential properties. The high thermal conduction of graphite is one of its most valuable qualities, permitting its use in the fabrication of heat exchange equipment. Impregnated graphite is practically not eroded at high temperatures even by strong mineral acids, including phosphoric acid, by alkali hydroxides, hydrofluoric acid, etc. It is subject to erosion only by strong oxidizers.

The application of impregnated graphite is restricted by its porosity, since various synthetic resins recently used for the elimination of porosity by impregnation do not withstand temperatures higher than 150-200°. The impregnation of graphite with solutions of mineral salts would permit its application at higher temperatures, but experiments in this respect have not yet given positive results.

Graphite is now impregnated mainly with phenol-formaldehyde resin and, to a lesser extent, with organosilicon compounds. The impregnation of graphite articles is usually performed in an autoclave connected with a compressor and vacuum pump.

By alternating pressure and rarefaction in an autoclave, it is possible to decrease graphite porosity from an initial 30-40% to 10-15%. The mechanical strength of impregnated graphite is considerably higher than that of graphite without impregnation. Graphite products, impregnated with phenol-formaldehyde resin, are subjected to heat treatment by a process generally adopted for the polymerization and curing of these resins.

The following table gives technical characteristics for graphites of two plants before and after impregnation with phenol-formaldehyde resin:

	Plant 1		Plant 2	
	Before	After	Before	After
Specific gravity, g/cu cm	2.25	2.07	2.27	2.03
Volume weight, kg/cu dm	1.57	1.85	1.38	1.5
Porosity, %	30.2	--	39.4	22.9
Tensile strength, kg/sq cm	70	180	67	121
Compressive strength, kg/sq cm	260	1,950	241	781
Heat conductivity at normal temperature, cal/in/hr/°C	--	--	94	97
Thickness of impregnated layer	--	8	--	30
Permissible temperature of application, °C	--	180	--	180

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Apparatus and parts, fabricated out of impregnated graphite, are being assembled by gluing with phenol-formaldehyde adhesives and with various glues. The adhesiveness of these gluing materials with impregnated graphite amounts to 25-30 kg/sq cm.

Threaded joints are also applicable for graphite parts. Impregnated graphite may be machined on metal-cutting machine tools. At present, some plants use impregnated graphite in the form of lining tiles or parts of chemical equipment.

Vinipplast is the oldest of the structural materials used in the Soviet Union during the postwar period as substitutes for nonferrous metals. Its application in the chemical industry was initiated in 1945 - 1946.

Although the properties of vinipplast and the conditions for its application have been described in technical literature in sufficient detail, new data on its behavior under various operational conditions have appeared recently. In addition, certain modifications and improvements have been introduced into the technology of vinipplast application as an independent or lining material.

It is generally known that the wide application of vinipplast is attributed to its valuable properties, including high chemical stability, weldability, thermoplasticity, and machinability. The negative properties of vinipplast include inadequate thermal stability, brittleness at temperatures lower than minus 20°, high coefficient of linear expansion, warping at sharp changes in temperature, etc.

Vinipplast is practically resistant to the action of almost all mineral and organic acids, solutions of alkalies and salts, and the majority of solvents and gases. However, it deteriorates in oxidizers, aromatic and chlorinated hydrocarbons, and certain other media.

Vinipplast is easily machinable under conditions where the cutting speed does not exceed 700 m/min and when effective elimination of heat is provided. Upon uniform heating from 80 to 180° C, vinipplast becomes soft and plastic. This permits the fabrication of vinipplast products by pressing, stamping, and molding.

The welding of vinipplast is based on its property to become soft with no modification of chemical stability when heated for a short period. Wire from 2 to 8 mm in diameter, made out of vinipplast, is used for welding rods. Types of joints in welding vinipplast are similar to those obtainable in welding metals. Vinipplast articles may be joined also by means of special glues.

Vinipplast is used for the fabrication of various equipment and fittings, such as containers of various sizes and intricate shapes, centrifugal pumps, valves, pipe elbows, and tees, condensers, injectors, ventilation pipes, etc. Pipelines made out of vinipplast may be used under pressure up to 5 atm. Armored vinipplast pipelines have been in operation for a number of years, showing good results.

In addition, vinipplast may be used as a lining material for the protection of equipment against active and corrosive substances. Vinipplast film 0.5-1.0 mm thick is used for lining, being glued to the metal surface to be protected. Where a thicker lining -- up to 3 mm -- is used, vinipplast is attached to metal walls with bolts.

Large rectangular containers are made out of vinipplast plates, at least 5-10 mm thick, which are welded together. All joints must be covered with glued-on vinipplast foil or treated with paste made on a base of phenol-formaldehyde resin.

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Engineer A. V. Goryaninova has recently conducted tests studying the strength properties of viniplast which has been under constant tension and also under the combined effect of three factors -- temperature, loads, and active medium. The results have shown that the mechanical strength of viniplast decreases under such conditions and the field of its application as a structural material becomes more limited.

A load of over 200 kg/sq cm causes creep of viniplast with increasing deformation rate, leading to fracture. A load of 50 kg/sq cm induces deformations in welded joints equal to the deformations of base material under a load of 200 kg/sq cm. The high creep of viniplast under constant load and the low strength of welds, are thus significant deficiencies of this material, especially in operation under pressure. For elimination of these faults, viniplast constructions have to be either reinforced with metal bindings or enclosed in metal housings. In these cases, the considerable difference in the coefficients of expansion of viniplast and iron must be taken into consideration, and the viniplast component of the apparatus has to be made smaller than the inner volume of the metallic enclosure.

The rate of welding -- 0.2 m/min for a single-row joint -- is considered inadequate. Recently a new method has been developed for welding viniplast without welding rods by forcing together under high pressure the pieces to be welded after preheating their edges. The method, being very productive, employs a specially designed machine tool with pressing rolls, preheating burner, and driving gear.

Despite the deficiencies of viniplast, this material continues to be an essential substitute for nonferrous metals. At some chemical plants, the length of viniplast pipelines is measured by the tens of kilometers. Several hundreds of viniplast linings have been installed instead of lead linings in the electrolysis shops of the industry of nonferrous metallurgy, and there are numerous other cases of viniplast application.

Examination of the properties of various substitute materials reveals tremendous opportunities for saving nonferrous metals. These opportunities must be widely utilized.

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